VTT Technical Research Centre of Finland

The future of food packaging

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The Future of Food Packaging

Ali Harlin, Heli Kangas,
Ulla Forsström, Mika Vähä-Nissi

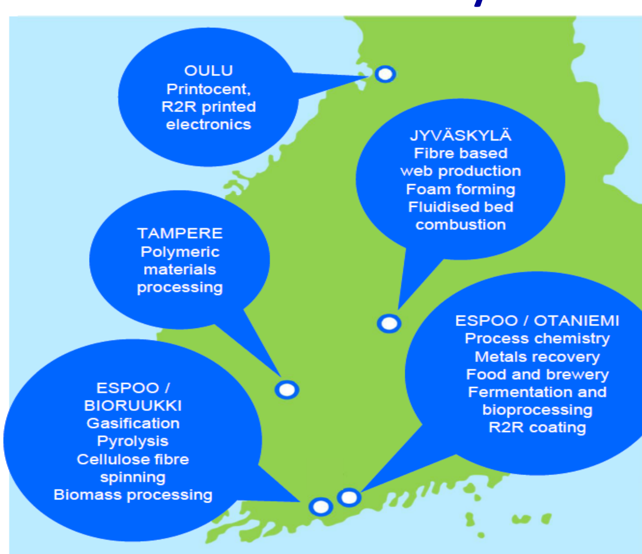
ICCG 12, June 12th 2018,
Frankfurt, Introduction session

VTT

Background and Trends

- Increasing number of consumers want to use less time for cooking, and therefore they prefer to eat on move or easy to cook meals,
- Consumers and NGOs demand for materials made from bio-based and sustainable resources that are recyclable, carbon neutral, and have low environmental and health impacts,
- Brand owners and packaging industry see a trend towards green materials a fact with real value, and there is a need to replace potentially hazardous materials,
- Packaging remains an excellent and sustainable tool for preserving food, avoiding food waste, and ensuring efficient use of limited resources with an ever increasing value.

VTT Pilot Plants for Packaging and Bio and Circular Economy 2018



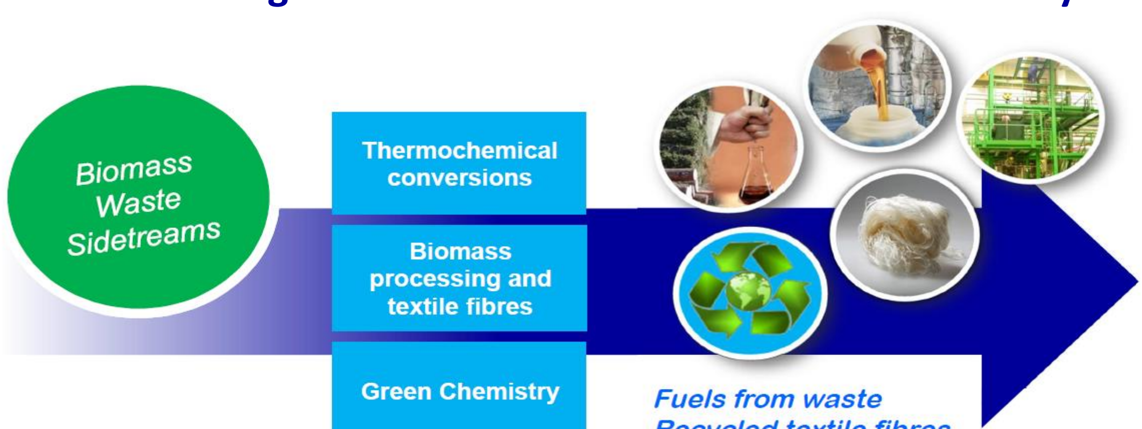
Key features for VTT pilots
- Covers the development chain from raw materials to end products
- Two types of pilots: Process specific and multi-purpose
- Scale-up of own and customers technology development
- Main customers large companies
- SME:s varies by pilots, up to 50%
- Customer projects ~ 40%

Bioruukki Pilot Centre - Efficiency, Speed and Low Risks to Development with Piloting and Demonstrations

- A new piloting ecosystem for process industry scale-up and demonstrations.
- A former printing plant transformed to world scale R&D centre.
- Located close to Otaniemi campus.

BIORUUKKI IS THE LARGEST OPEN PILOT FACILITY IN BIOECONOMY IN NORTHERN EUROPE

Bioruukki Pilot Ecosystem – An Integrated Enabler to Accelerate High Value Business in Bio & Circular Economy



Fuels from waste
Recycled textile fibres
Chemicals from cellulose
Bio-oil from forest residues
Solar energy stored as liquid fuel
Design of new sustainable processes

Biomass Processing and Products

Development of resource efficient and cost competitive process and product concepts based on renewable raw materials

BIOMASS PRETREATMENT
- Mechanical, chemical and enzymatic processing of raw materials

UPGRADING FRACTIONS
- Lignin up-grading technologies
- Recovery of high-value components
- Sustainable dissolution processes

WEB BASED FIBRE PRODUCTS
- Foam forming of thin and thick webs
- Moldable web
- NFC films and membranes
- Barriers and functional coating

BIO-BASED HYBRID STRUCTURES
- Biocomposite production technologies, esp. extrusion
- Man-made fibres and yarns
- Biopolymer foams, 3D-structures and functional materials

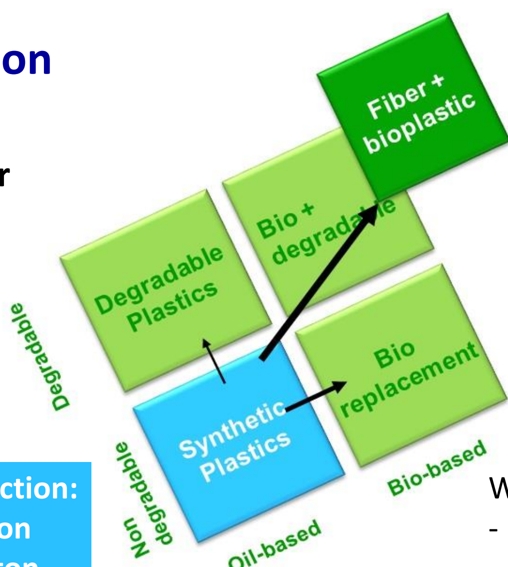
Biomaterial Products

Our competence areas are

- Biopolymer and fibre foams
- High-performance fibre composites
- Tailoring of fibres and biopolymers
- Biomaterial process development
- Bio- and circular economy materials

Our Vision

Replace or reinvent!



Many options, better optisms!

Plastics production:
1950 ~ 1.5 Mton
2015 ~ 322 Mton
2025 ~ 400 Mton

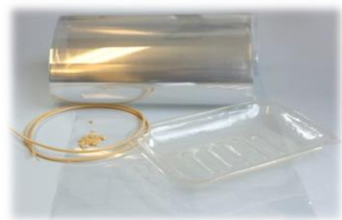
With existing P&P capasity we can
- Increase recycling from 22% to 36%
- Reduce waste by 74 Mton
- Increase biodegradable by 12 Mton
- Increase biocontent 0.6% -> 23%

Examples of Structures Possible From Cellulose

Paper like pouches
- Aesthetic layer
- Support
- Barrier
- Hot melt adhesive

Clear packaging films
- Aesthetic layer
- Support
- Barrier
- Hot melt adhesive

Moldable board trays
- Aesthetic layer
- Support
- Barrier
- Hot melt adhesive

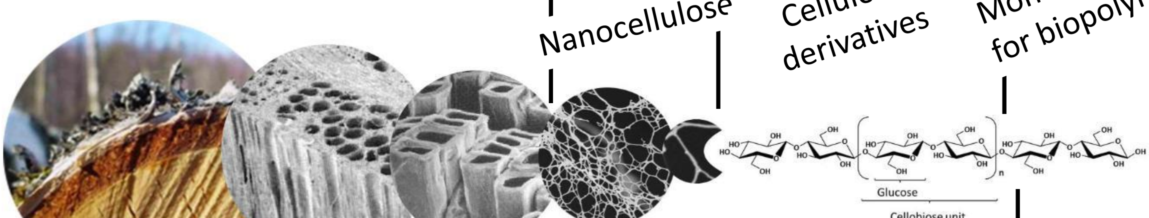


From Natural Composites to Bio-based Polymers

Nanocellulose

Cellulose derivatives

Monomers for biopolymers



m	cm	mm	µm	nm	Å
Wood or plants	Fibers in wood matrix	Cellulose Fiber	Micro Fibrils	Nano Fibrils	Molecular Structure

Plastic Like Nanocellulose Films

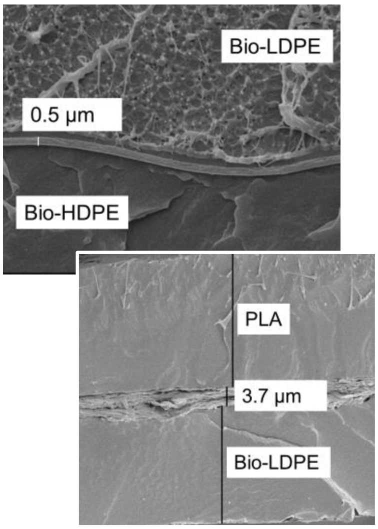
- Produced with a roll-to-roll SutCo surface treatment pilot line using casting method,
- Several meters of ”plastic-like” film
- Properties depend on formulation,
- Good:
  - OTR <0.1 $cm^3/m^2/d$ (0% RH; 15 µm)
  - Temperature resistance (200°C)
  - Tensile strength (200 MPa)

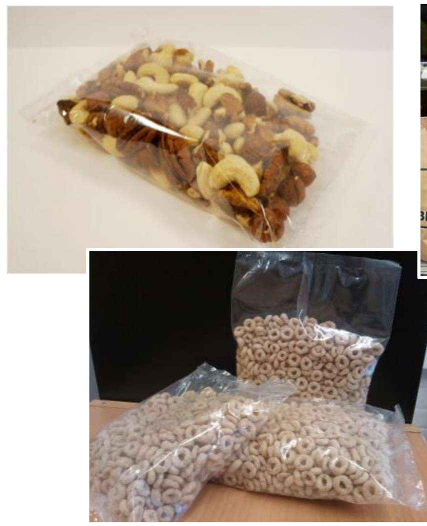
Based on patent application (Tammelin et al., Method for the Preparation of NFC films on Supports)

SutCo Surface Treatment Line

- Modular semi-pilot for evaluation of new product concepts
- Selection of coating methods
- Possible applications:
  - Nanocellulose films
  - Enhancement of bioplastics
  - Barrier development
  - Simple electronics
  - Functional surfaces
  - Bioactive functionalities
  - Other customized applications

Nanocellulose Films and Barrier Coatings

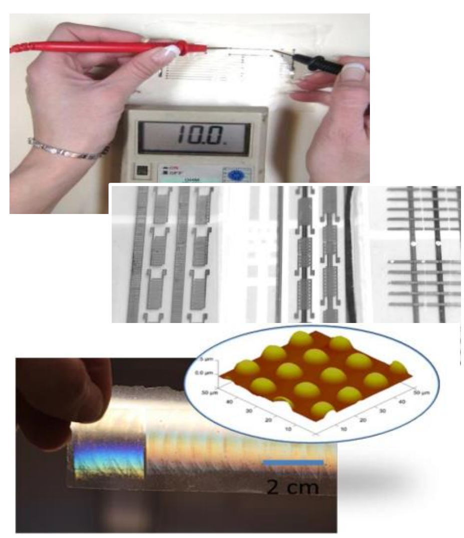




WO2013/060934,
PCT/FI2015/050835,
FI2016/5075

CNF Films for Optoelectronics and Smart Packages

- Thin, inexpensive, flexible and biodegradable material as substrate for conductive structures and organic transistors,
- Paper not a viable option due to its structure, and printing on plastics can be challenging,
- Smooth and dense film surface,
- Silver ink can be used to print conductive structures on the surface,
- Structures sintered at 150ºC for 1 h,
- Micropillar patterns create optical effects



RESEARCH CASE

Hybrid Package: Bag-In-Box

Current state-of-the-art

100% fossil-based inner pouch

- Moisture barrier

VTT's solution

100% bio-based inner pouch

- Moisture barrier
- Oxygen barrier
- Mineral oil barrier

RESEARCH CASE

40-50% Reduction in Light Absorption

Commercial 1 HDPE

Commercial 2 Multilayer

Bio-HDPE + CNF coating

RESEARCH CASE

Bio-HDPE + CNF Coating as Mineral Oil Barrier:

Reduction in Mineral Oil Migration vs Uncoated film

n-decane (C10, linear aliphatic)	**98%**
isobutylbenzene (C10, aromatic)	**98%**
1-cyclohexylbutane (C10, cyclic aliphatic)	**98%**
1-cyclohexylheptane (C13, cyclic aliphatic)	**97%**
1-cyclohexyldecane (C16, cyclic aliphatic)	**83%**

In addition,
99% reduction in oxygen transmission!

29/06/2018 Disclaimer: The commercial product used herein not related to the invention 19

RESEARCH CASE

Stand-up Pouches from Renewable Materials and CNF

- **Lightweight 100% bio-based stand-up pouches,**
- **High performance in both oxygen, grease and mineral oil barrier properties,**
- VTT's HefCel technology provides a low-cost method for the production of nanocellulose,
- Resulting in a tenfold increase in the solids content of nanocellulose.

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RESEARCH CASE

INCOM VTT

Cellulose Fiber Reinforced Thermoformable Materials

Bio-based **poly(lactic acid) (PLA)** and **polypropylene (PP)** as matrix polymers

- **Wood based cellulose fibres** with 3 different lengths were tested

→ Micro-sized cellulose fibers gave smooth and thermoformable film

→ Compounds with fiber loadings of **10-30 wt-%** could be thermoformed

- The stiffness was improved slightly

→ Plasticizing effect of the additives had an opposite effect than fibres

VTT

Technical University of Denmark DTU

econcore economic core technologies

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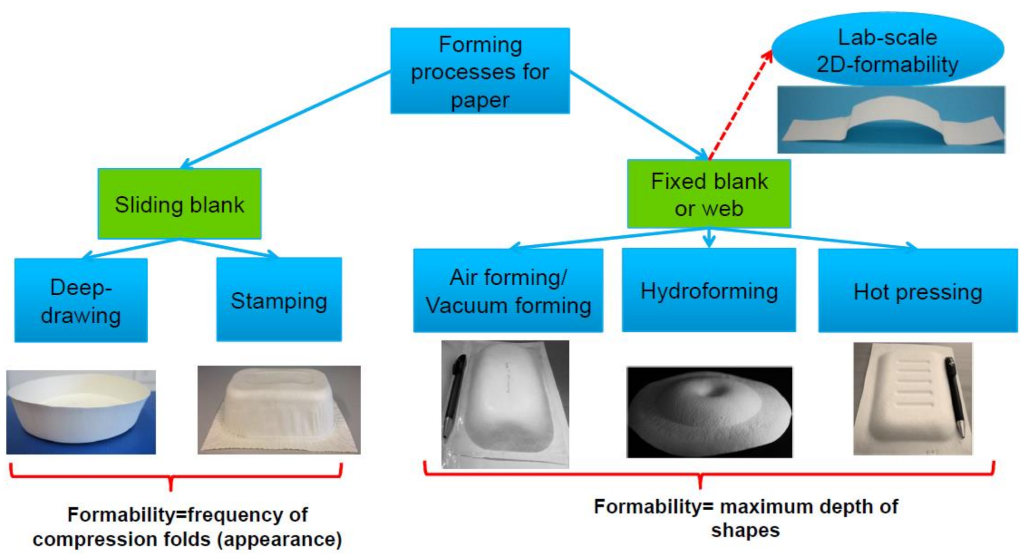
RESEARCH CASE

VTT

3D Forming & Formability of Paper and Paperboard



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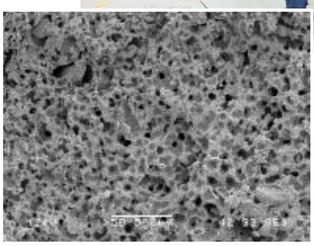
RESEARCH CASE

Light-weight PLA Foam Development



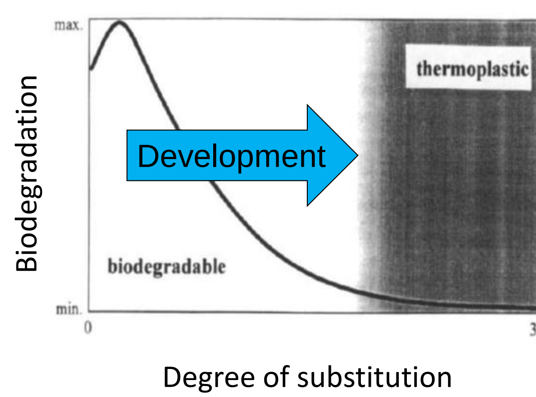
Extrusion foamed and expanded PLA

- Sustainability by replacing oil-based components
- Light-weight, high insulation
- 100% bio-based

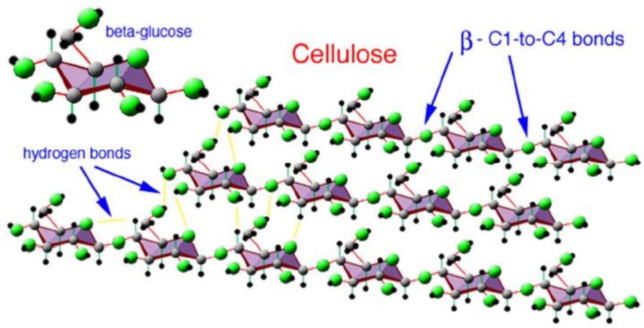
Applications in e.g. packaging, construction and transport

Biodegradability

- Pure lignocellulosic materials biodegradable,
- To produce regenerated cellulose films, cellulose need to dissolved in viscose process,
  - Green alternative is ionic liquids
- Cellulose derivatives soluble in common solvents, and derivatives with low DS biodegradable,
- CNF and paper are naturally biodegradable, but with no water resistance
  - If biodegradable wet strength agent or all-cellulose approach used, the biodegradability of the material could be retained.

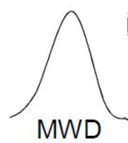


Cellulose vs. Polyethylene

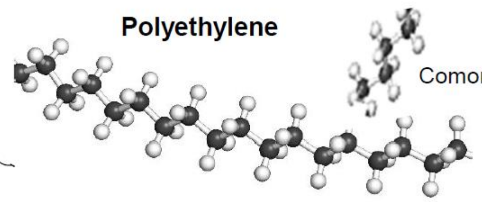


Complex structure

Controlled structure



Polyethylene



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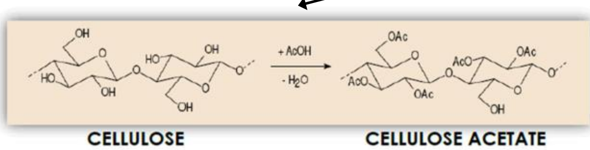
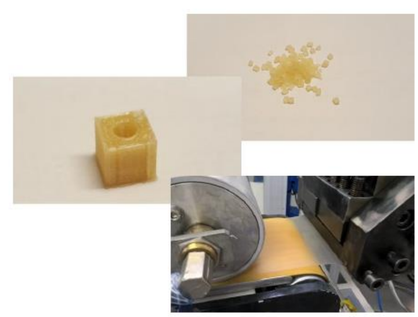
RESEARCH CASE

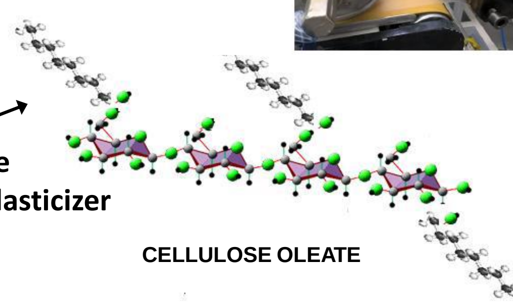
Thermoplastic Cellulose

Repulsive groups
+ external plasticizer





Modified cellulose chain + internal plasticizer



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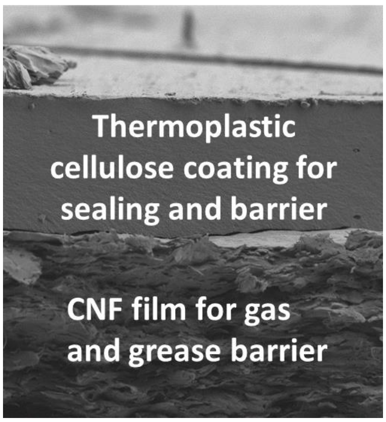
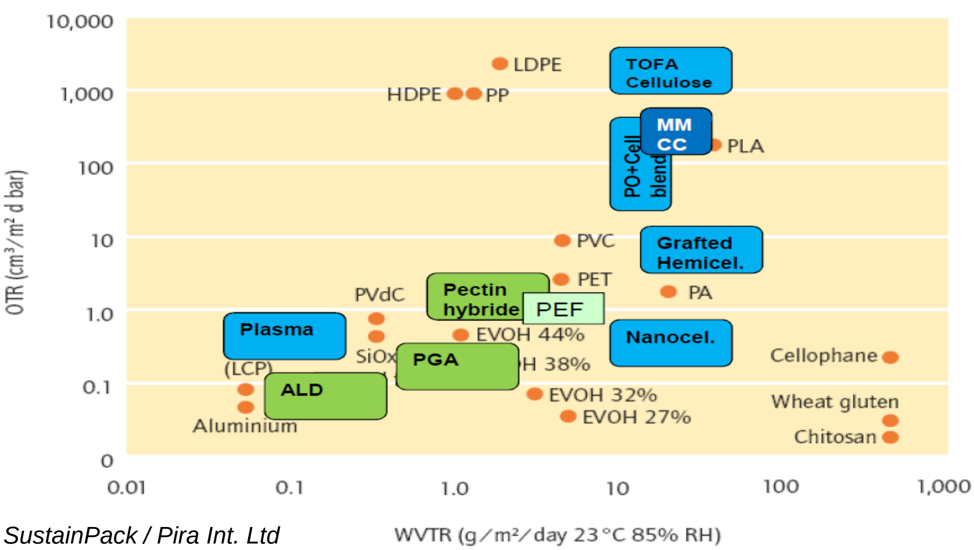
RESEARCH CASE

Cellulose-based Multilayer Packaging Material
(Ellen MacArthur Foundation & EcoPack Challenge Winner 2018)



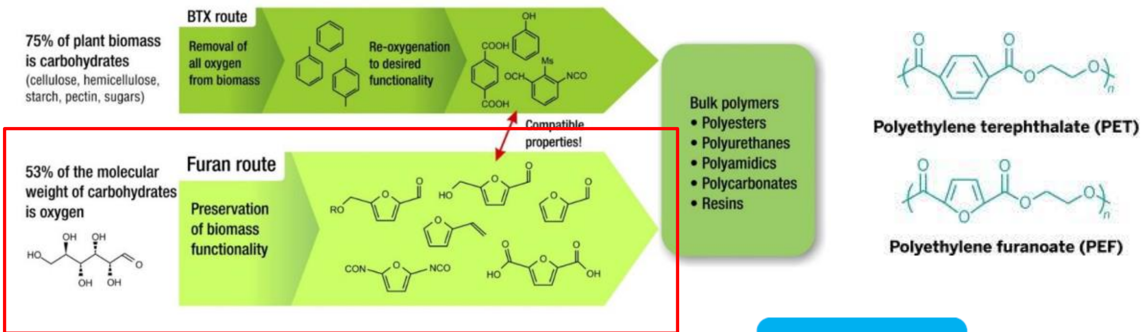
Barrier properties of typical coatings
(normalized to 100µm thickness)



Source: SustainPack / Pira Int. Ltd

RESEARCH CASE

2,5-Furandicarboxylic acid (FDCA)



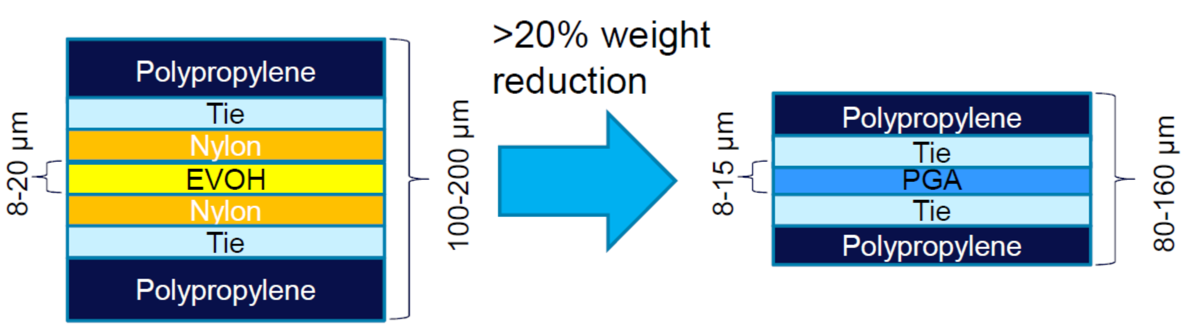
- Bio-based aromatics (furans) can be produced from carbohydrates with high atomeconomy.
- They can be produced with a small number of process steps from a renewable raw material – even side stream or waste can be utilized.

Better barrier properties than PET

A chance to replace certain markets

RESEARCH CASE

High Performance Biopolymers



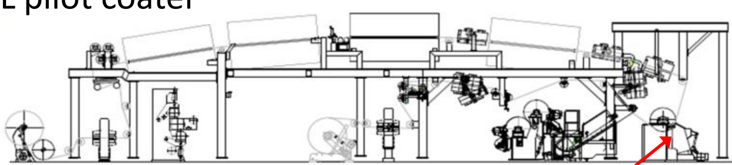
20% light-weighting potential in flexible retort packaging films.

PGA = Polyglycolic acid

RESEARCH CASE

Enabling Thin Layers on Paper: Foam CNF Application

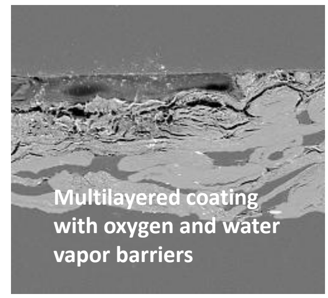
KCL pilot coater



CNF, solids content 3.0%

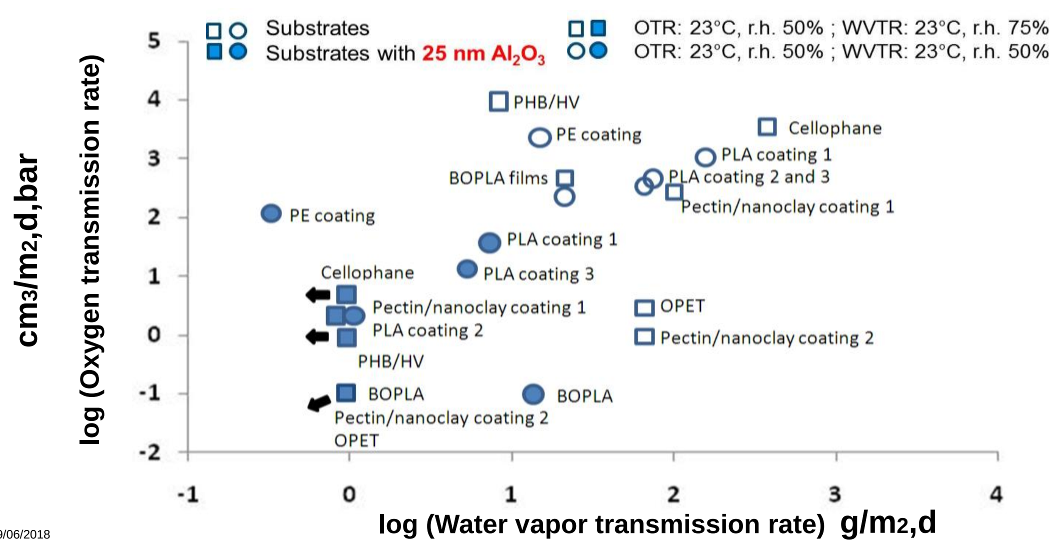
Foamed CNF, 90% air

Foam applicator



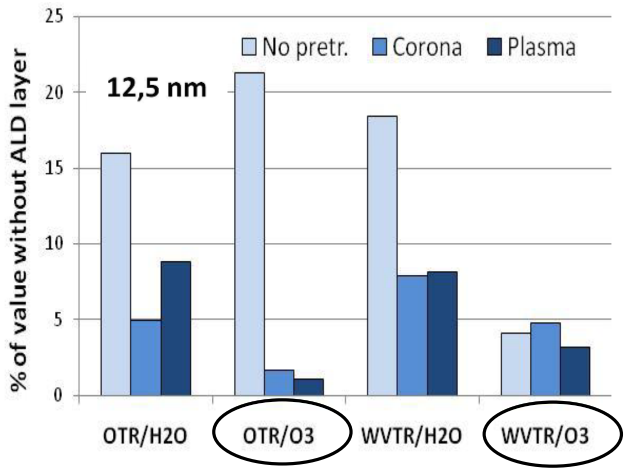
RESEARCH CASE

Improved Barrier with 25 nm of ALD Al_2O_3



RESEARCH CASE

Effect of Oxidant & Pretreatment on PLA-coated Board

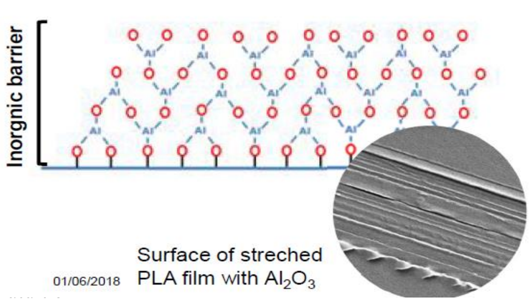


- Pre-treatments prior to the ALD can improve barrier properties,
- Surface chemistry affects nucleation and initial growth rate,
- Choice of oxidant affects barrier properties – denser Al_2O_3 films with O_3,
- Eveness of polymer-coating is of high importance for the ALD.

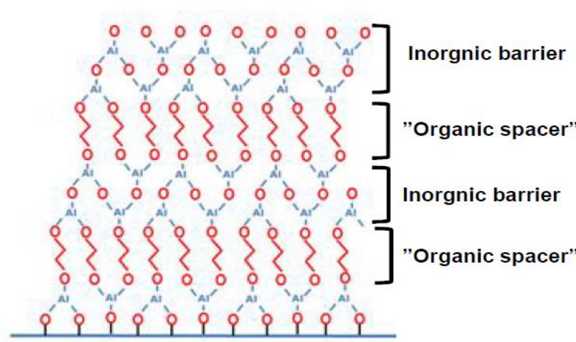
RESEARCH CASE

Flexibility Through Structural Tailoring

- Metal oxide layers are brittle
- Mechanical stresses and thick layers lead to impaired barrier
- There are indications that chemical bonding with base substrate is beneficial



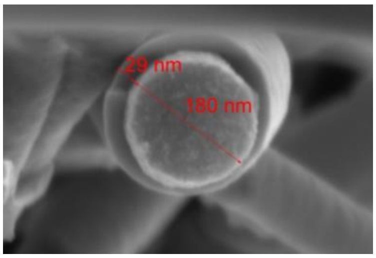
Surface of streched PLA film with Al_2O_3



- Flexibility & elasticity improved by dividing thick barrier layer into thinner stacks and separating these with flexible "organic spacer" layer

RESEARCH CASE

Understanding Nucleation & Film Growth on Polymers



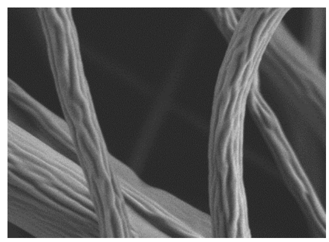
TiNbOx ALD layer on carbon fibres (made from PAN electrospun precursors)

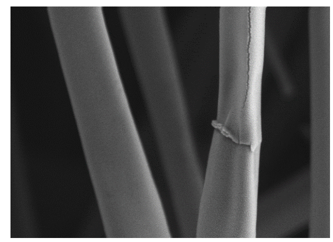
ATAPULT

Funded by: EC, FP7, FCH-JU, Grant agreement n° 325268) & Tekes

Cellulose acetate electrospun fibers with 2 and 30 nm Al_2O_3 ALD layer

ACADEMY OF FINLAND





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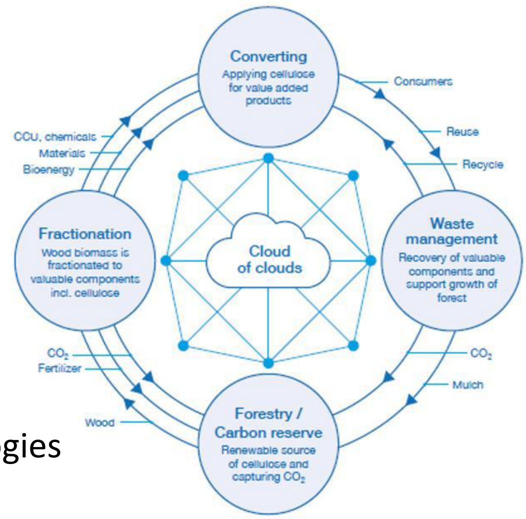
Next on: Material as Service

Complete offering:
- Raw material
- Recycling
- Waste management

New requirements:
- High flexibility
- Rapid applicability
- Consumer orientation
- Food processing technologies



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